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The main area of research continues to be spectral shape discrimination, what I have called profile analysis. Three areas continue to receive considerable attention. They are: 1) the cues available for detecting spectral changes as a function of the bandwidth of the stimulus, 2) how the number of components or density of the spectrum affects the ability to hear spectral changes, and 3) temporal effects--how duration of the stimulus appears to interact with other variables to influence the listener's ability to hear spectral changes. In the first two areas, we have used Berg's COSS analysis to great advantage, and we anticipate that we shall continue to utilize that procedure in our research.

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Progress Report for AFOSR-F49620-92-J-0139
Complex Auditory Signals
January 1993

This progress report covers the period from January, 1992 to January, 1993. First, we list the publications and papers in the process of publication. We have also presented a number of papers at the annual meetings of the Acoustical Society of America. These reports are the basis of the published articles and are not listed separately. Following the list of publications, a brief narrative section describes the research and integrates the particular research effort with the larger research problem or question. We conclude with a description of personnel: technical staff, graduate students and post-docs, and visitors.

PUBLICATIONS

1). Green, D.M. (1992) "The number of components in profile analysis tasks." Journal of the Acoustical Society of America, **91**, 1616-1623.

2). Berg, B.G. and Green, D.M. (1992) "Discrimination of complex spectra: Spectral weights and performance efficiency." Auditory Physiology and Perception, edited by; Y. Cazals, L. Demany and K. Horner, Pergamon Press, **83**, 373-379.

3). Green, D.M. and Dai, H. (1992) "Temporal relations in profile comparisons." Auditory Physiology and Perception, edited by; Y. Cazals, L. Demany and K. Horner, Pergamon Press, **83**, 471-478.

4). Dai, H. and Green, D.M. (1992) "Auditory intensity perception: Successive versus simultaneous, across-channel discriminations." Journal of the Acoustical Society of America, **91**, 2845-2854.

5). Berg, B.G., Nguyen, Q.T., and Green, D.M. (1992) "Discrimination of narrow-band spectra. I: Spectral weights and pitch cues." Journal of the Acoustical Society of America, **92**, 1911-1918.

6). Green, D.M., Berg, B.G., Dai, H., Eddins, D.A., Onsan, Z., and Nguyen, Q. (1992) "Spectral shape discrimination of narrow-band sounds." Journal of the Acoustical Society of America, **92**, 2586-2597.

7). Dai, H. and Berg, B.G. (1992) "Spectral and temporal weights in spectral-shape discrimination." Journal of the Acoustical Society of America, **92**, 1346-1355.

SUBMITTED FOR PUBLICATION

8). Zera, J. and Green, D.M., "Detecting temporal asynchrony with asychronous standards." Accepted for publication in the Journal of the Acoustical Society of America, with a tentative date of publication in March, 1993.

9). Green, D. and Dai, H., "Suppressing a contaminating cue in discrimination experiments." Submitted for publication to Psychological Bulletin.

10). Dai, H. and Green, D.M., "Discrimination of spectral shape as a function of stimulus duration." Submitted for publication to the Journal of the Acoustical Society of America.

11). Zera, J., Onsan, Z., Nguyen, Q., and Green, D.M., "Auditory profile analysis of harmonic signals." Submitted for publication to the Journal of the Acoustical Society of America.

12). Zera, J. and Green, D.M., "Detecting temporal onset and offset asynchrony in multicomponent complexes." Accepted for publication in the Journal of the Acoustical Society of America, with a tentative date of publication in February, 1993.

13). Eddins, D., "Amplitude modulation detection of narrow-band noise: effects of absolute bandwidth and frequency region." Accepted for publication in the Journal of the Acoustical Society of America, with a tentative date of publication in January, 1993.

14). Zera, J. and Green, D.M., "Detecting asynchrony in harmonic components: the effect of starting phase." Submitted for publication as a letter to the Editor in the Journal of the Acoustical Society of America.

15). Green, D.M., "Auditory Intensity Discrimination." Chapter submitted for publication for volume 3 of the Springer Series in Auditory Research: Human Psychophysics, published by Springer-Verlag.

16). Eddins, D., and Green, D.M., "Temporal Integration and Temporal Resolution." Chapter submitted for publication for volume 6, HEARING, in The Handbook of Perception and Cognition, published by Academic Press.

DESCRIPTION OF RESEARCH

The main area of research continues to be spectral shape discrimination, what I have called profile analysis. Three areas continue to receive considerable attention. They are: 1) the <u>cues</u> available for detecting spectral changes as a function of the bandwidth of the stimulus, 2) how the <u>number of components</u> or density of the spectrum affects the ability to hear spectral changes, and 3) temporal effects--how <u>duration of the stimulus</u> appears to interact with other variables to influence the listener's ability to hear spectral changes. In the first two areas, we have used Berg's COSS analysis to great advantage, and we anticipate that we shall continue to utilize that procedure in our research. Let me briefly summarize what we know and would like to know in each of these areas.

Cues

We now believe that spectral shape discrimination is mediated by three different cues. The saliency of these cues depends on the total width of the spectrum. For spectra wider than three or more critical bands, the cues responsible for spectral shape discrimination are simultaneous comparisons of level in different critical bands. Pitch and envelope cues are largely irrelevant; only level comparisons--independent of the phases of the components--are used. Reference 2 presents the evidence for this claim. For medium-sized spectra, one or two critical bands in width, changes in spectral shape are discriminated by changes in pitch. The center of gravity of the spectrum is altered by changes in the level of the same components of the standard spectrum, and this change in pitch is the most salient cue. Reference 5 presents the evidence for this claim. For very narrow spectra, less than one critical band, changes in spectral shape are discriminated by changes in the power spectrum of the envelope. Reference 6 reviews the evidence for the envelope cue. The paper has finally been published, after a very long review process.

Number of components

How the number of components influences spectral shape discrimination has become an area of considerable research interest and somewhat conflicting experimental results. The experimental situation is this. The standard spectrum has a number, m, of equal amplitude components, usually equally spaced in logarithmic frequency. The signal is a change in the central component of the standard. The issue is how the ability to detect such a signal depends on the number of components in the standard. In our earliest papers (Green, Kidd, and Picardi, 1983, and Green, Mason, and Kidd, 1984), we found nearly a 10-dB improvement in threshold when we measured the detectability of a central component for (m =

3) and a (m =11). More components led to better detection. I should add that in all these experiments the density of the spectrum was such that any critical band contained only one spectral component. Obviously, as more and more components fall within a single critical band, the increase in level of a single component will exert comparatively less change on the level of that critical band.

Later results with very practiced observers suggest that there was less difference between the two conditions, although more components still generally led to better detection. Henn and Turner (1990) published some results that often showed no change with the number of components, and for several conditions detection actually become poorer as the number of components increased. In Ref. 1, I reviewed both the past data and theory, and showed that extensive practice is needed to produce performance that mirrors the prediction of the theory. G. Kidd has sent me a recent manuscript, in which he concludes that the relationship between m and the decrease in threshold is largely a matter of individual differences among the listeners. In a paper now in draft form, we show that signal duration--simply how long the sound is on--interacts with the number of components in the spectrum. For long duration (t>100ms), increasing m improves the ability to detect change; for short durations (t<10 ms), increasing m leads to poorer ability to detect spectral change.

Duration

Signal duration seems to have a profound effect on many of the standard profile results (Refs. 3, 4, 7, and 10). Almost all the earlier work involved a signal duration of at least 100 ms. Recently, we have been exploring briefer (10 ms) signals. Not only is the threshold for spectral change elevated by the brief durations, but notable changes occur in the data as a function of frequency spacing and signal frequency. Some of these results are summarized in Ref. 10, and further work on this issue is anticipated. In Ref. 10, we argue that thresholds for the detection of spectral change can be predicted by assuming that the auditory filter narrows in time after the onset of the signal. We estimated that the auditory filter width changes by about a factor of 6 within 10-30 ms after signal onset. We are planning additional experiments to explore this idea.

Other Related Topics or Collaborative Research

Harmonic Complexes

In addition to this work, Dr. Jan Zera of the Chopin Academy of Music, Warsaw, Poland, and I continue our collaborative efforts.

One such effort is a study of the spectral change detection using

harmonic complexes (Ref. 11). If the signal is a change in the level of a single component of a harmonic complex, then the threshold for this change as a function of frequency is a steeply rising function, quite different in appearance from what we found with logarithmic complexes. We argue that these differences arise from masking. Whereas in a logarithmic complex one component occupies a single critical band; in harmonic complexes, more and more components fall into the same critical band as the frequency of the components increases. Thus, the ability to detect a change in a single component is reduced. This nonuniform density (components per critical band) causes substantial differences in thresholds as a function of frequency. We can reconcile almost all these anomalous effects if we simply assume that the critical quantity for detecting spectral change is the relative change in level in a critical band, rather than in the change in level in the raw audio spectrum. Once this correction is applied, the results from the harmonic spectra strongly resemble the kind of results obtained with logarithmically spaced components, including the 'bowl' effect, namely, that the best detection occurs when the spectral change occurs in the middle of the complex.

Asynchrony Detection

In another collaborative effort with Dr. Zera, we began a series of studies on the perception of temporal onset and offset asynchrony in complex multitonal signals. In the standard sound, all components start and end at the same time. In the signal sound, one or more components of the complex starts at a different time from the remainder. Our first paper (Ref. 8) was submitted some time ago, and we recently read galleys on that paper. A second paper (Ref. 12) has also been accepted, and a third letter to the editor submitted (Ref. 14).

Asynchrony detection is an extremely complex process. The major findings are: 1) onset asynchrony is easier to detect than offset asynchrony by nearly an order of magnitude; 2) asynchrony of some low-frequency components (200-2000 Hz) is detectable when delayed only 1/4 of a period; 3) detecting temporal asynchrony is more acute for harmonic complexes than for logarithmic complexes. Our project for this year is to construct some theory to understand these results. The theory is still under construction, but it will undoubtedly relate to CMR and other simultaneous spectral comparisons.

Modulation detection of narrow bands of noise

This research was carried out by David Eddins, who is a third-year graduate student. He has been studying temporal resolution process using modulated noise and gap detection. Reference 13 is the third paper in his thesis. His general thesis is that the

temporal parameters are determined entirely by the bandwidth of the stimulus; the center frequency is irrelevant.

What is the optimum distribution to use to minimize a potentially confounding cue?

We developed a proof (Ref. 9) for why a rectangular distribution is the best way to randomize level in a profile experiment. Psychological Bulletin said it was a nice paper, but not sufficiently broad to interest the psychology community. If we would broaden it to include some topics in cognitive psychology, then they might accept it. Huanping and I are still considering whether or not we wish to revise it along the suggested lines.

Chapters

We have written two chapters reviewing certain areas of research and some of our current research. One (Ref. 15) concerns intensity discrimination and especially the recent work in CMR, CDD, and modulation interference. The second (Ref. 16) is a review of temporal phenomena in auditory perception. D. Eddins is the first author. Edited portions of this chapter should provide a convenient introduction to his thesis.

Personnel

The following people were supported from or contributed to the research carried out on the Air Force grant during the last three years. The current status of each is reported.

Technical Staff

Ms. Zekiye Onsan has secured an H-1 visa and works part time on the Air Force grant as an engineer technician.

Mr. Quang Nguyen continues as a laboratory technician and programmer.

Ms. Mary Fullerton continues as the secretary and bookkeeper for the laboratory.

Postdoctoral Fellows

Dr. Huanping Dai joined the laboratory on August 6, 1989. He received his doctoral degree from Northeastern University, where he was supervised by Dr. B. Scharf. He recently secured a permanent-resident visa, and has been appointed an assistant researcher in

psychology.

Dr. Beverly Wright received her doctoral degree from the University of Texas, where she was supervised by Dr. D. McFadden. She has been awarded an NIH postdoctoral fellowship, and joined the laboratory in June, 1991.

Graduate Students

Mr. David Eddins received his B. A. and M. S. degrees from the University of North Carolina at Chapel Hill, where he worked with Dr. J. Hall. He has a Certificate of Clinical Competence in Audiology. He has begun his third year of graduate study at Florida.

Mr. Zhou Bin came to the laboratory from mainland China. He received his undergraduate degree in acoustics from Nanjing University. He also has advanced training in acoustics from the Wuhan Institute of Physics. He has begun his third year of graduate study at Florida.

Ms. Jung-mee Lee is a student from South Korea. She received her B. A. from Seoul University. She has begun her second year of graduate study at Florida.

Ms. Xiang Gu has begun her second year of graduate study at Florida. She is a graduate (1979-1983) of the Physics Department of the University of Nanjing, where she specialized in acoustics. She worked as an engineer at the Research Institute of TV and Electroacoustics in Beijing.

Sabbatical visitors

Dr. Jan Zera of the Chopin Academy of Music, Warsaw, Poland, arrived in the fall of 1990. He is a Fulbright Fellow. He will complete his third year at the laboratory in June, 1993.

Dr. Soren Bech of the Acoustics Laboratory, Technical University of Denmark, Lyngby, Denmark, arrived in April and worked in our Laboratory through May, 1992.

Dr. Gerald Kidd and Christine Mason arrived in January and worked until June, 1992. They were here on a sabbatical leave from Boston University, Department of Communication Disorders, Sargent College of Allied Health Professions, Boston, Massachusetts.